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(54) Measuring ink concentrations in printed matter

(57) A method and apparatus for measuring ink concentrations in printed matter is described. The apparatus comprises: scanning means (105) for measuring the colour density of check points on a standard printed sheet (110) through a coloured filter or through a plurality of separate differently coloured filters and for measuring the colour density of points on a test printed sheet (106) corresponding to the check points on the standard sheet through the same coloured filter or filters; means for determining from the colour density measurements the concentration of the or each ink printed on the standard sheet (110) at each check point and the concentration of the or each ink printed on the test sheet (106) at each point corresponding to a standard sheet check point; and means for determining, for each check point and for the or each colour of ink, deviation coefficients representing the difference in ink concentration between the sample and test sheets.

FIG.3

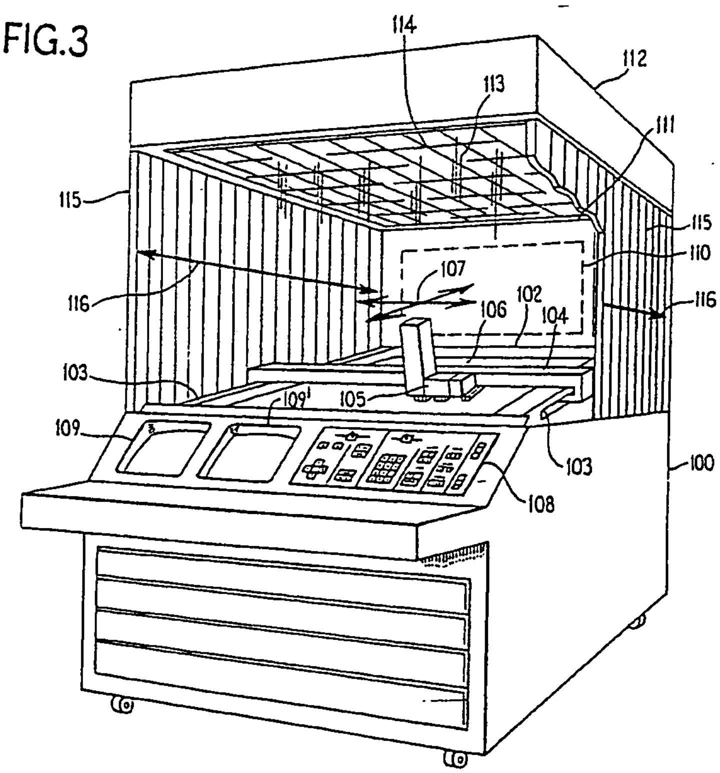

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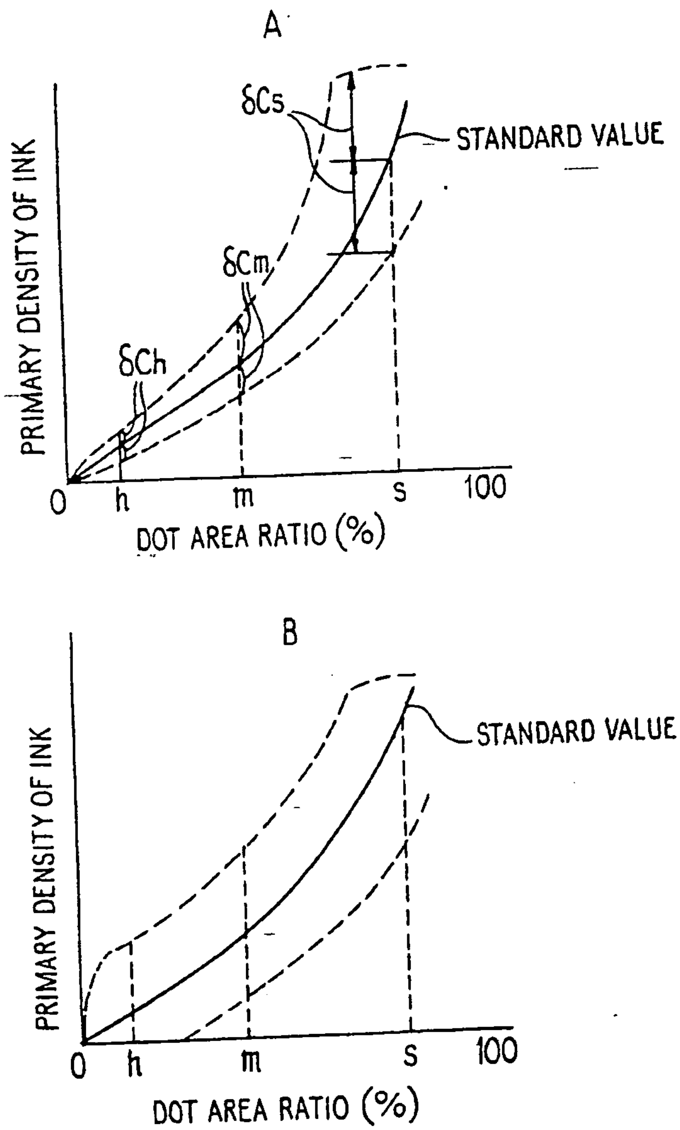
FIG.1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δCm
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PRIMARY DENSITY OF INK
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FIG.2

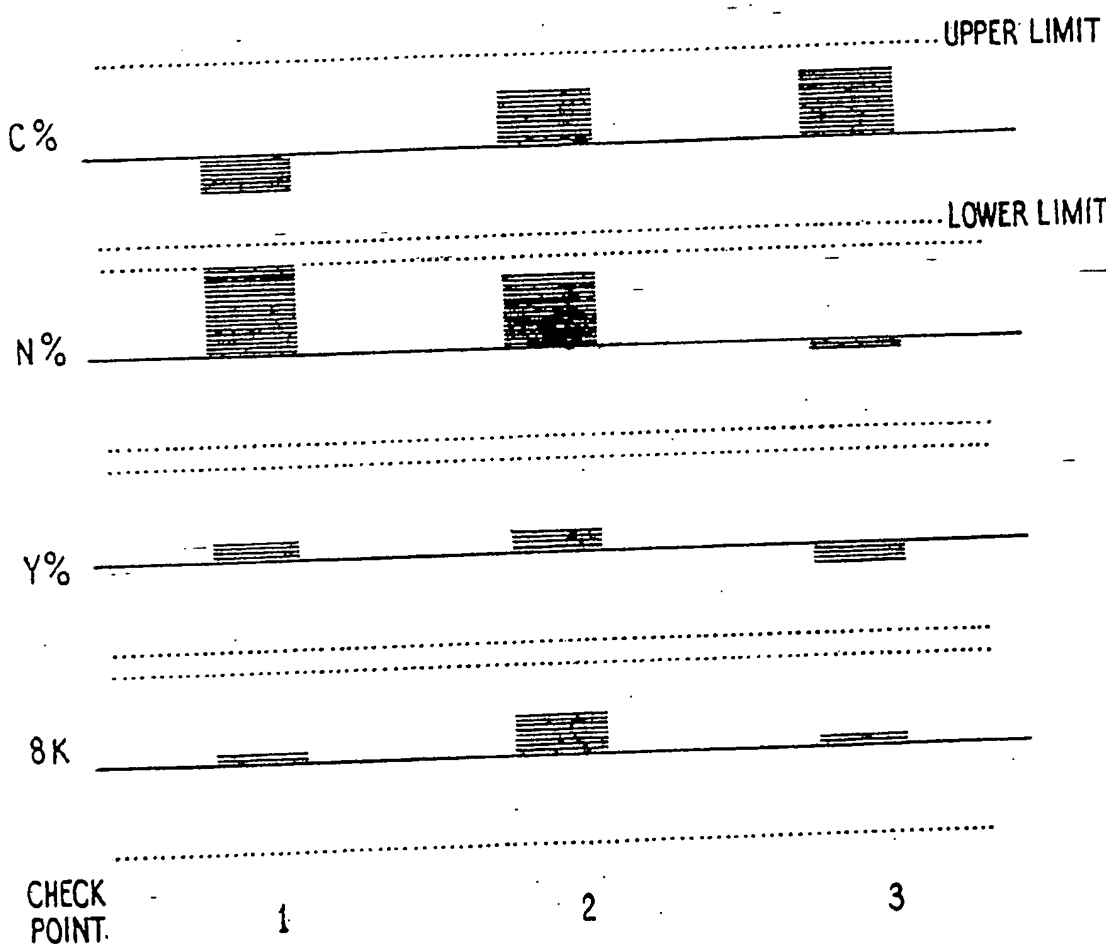

FIG.3

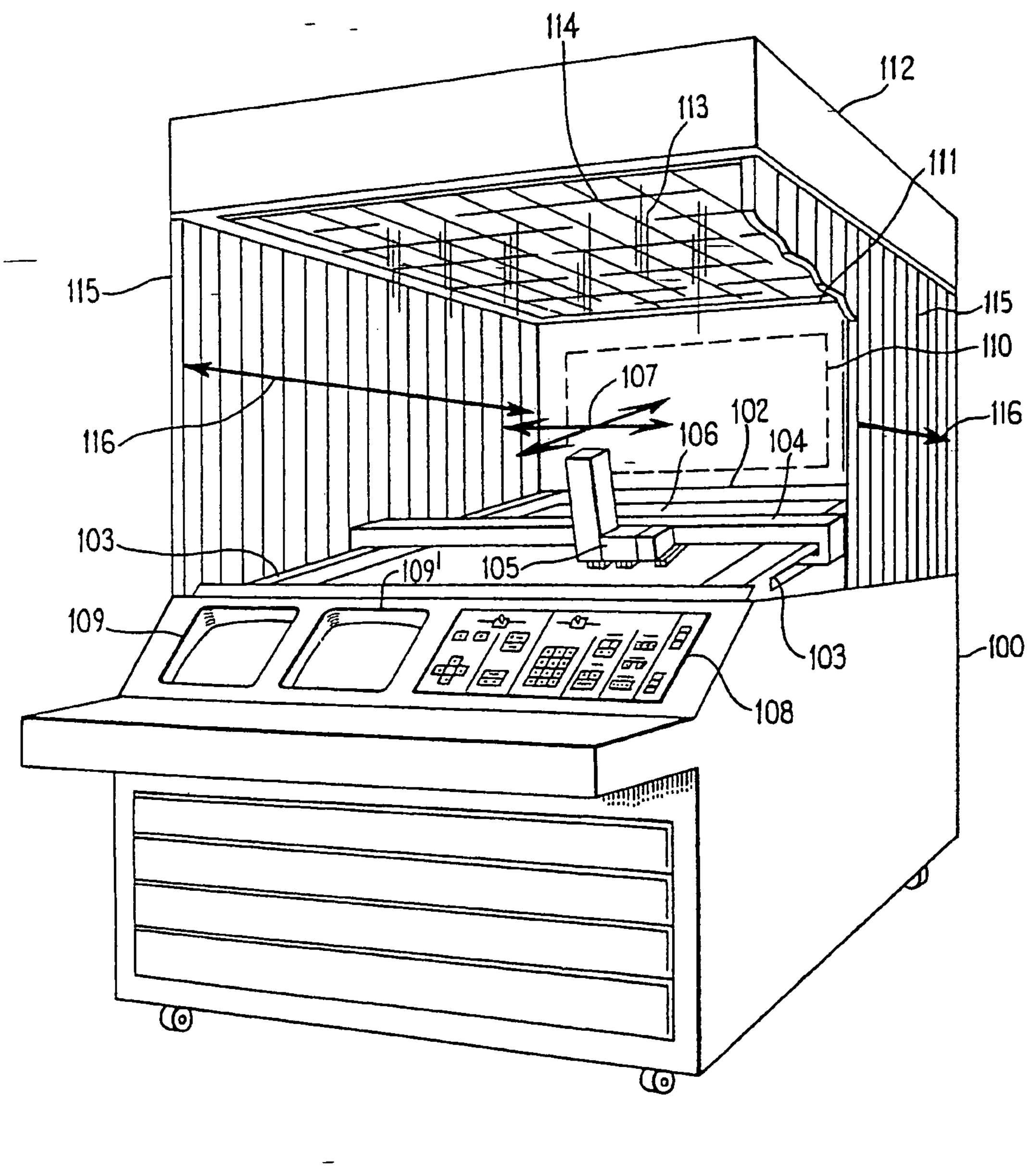
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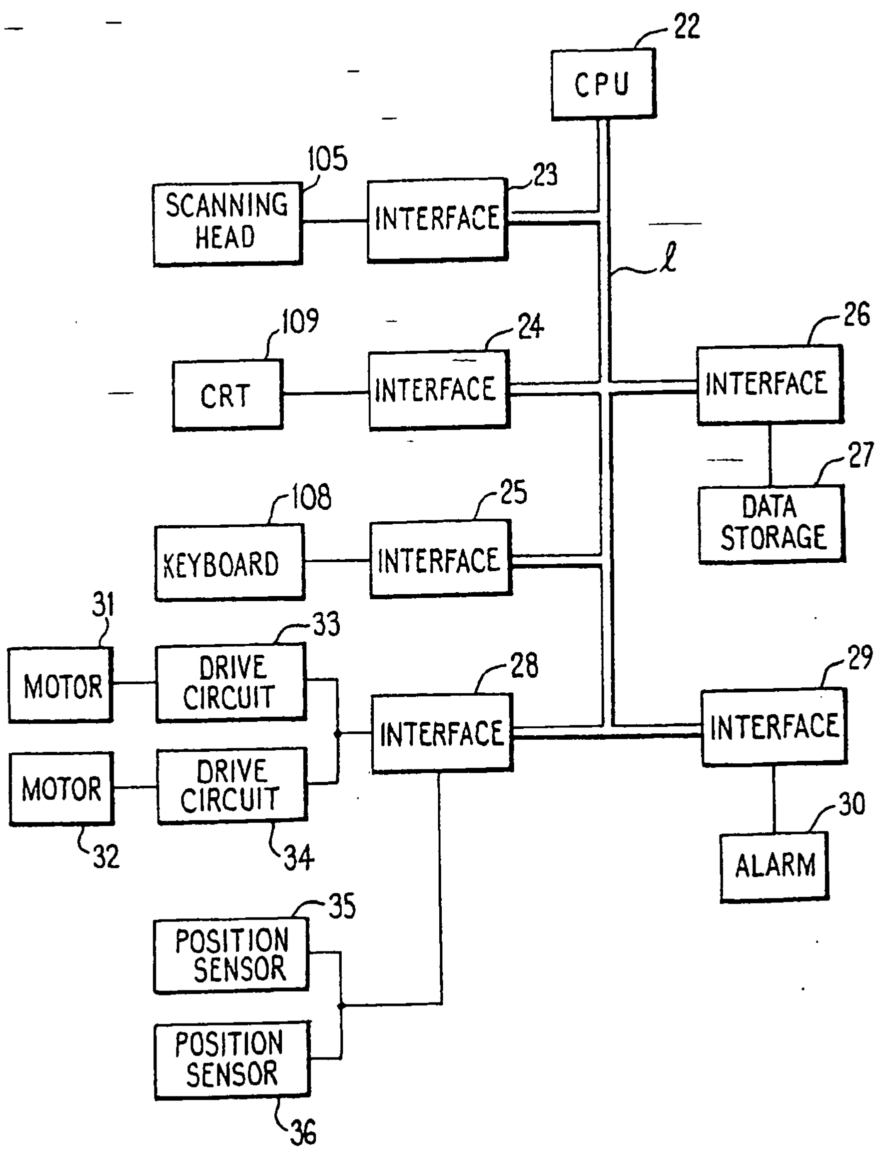
FIG.4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INTERFACE
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MOTOR
33
DRIVE CIRCUIT
28
INTERFACE
29
INTERFACE
MOTOR
32
DRIVE CIRCUIT
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ALARM
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POSITION SENSOR
POSITION SENSOR
36

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FIG.5

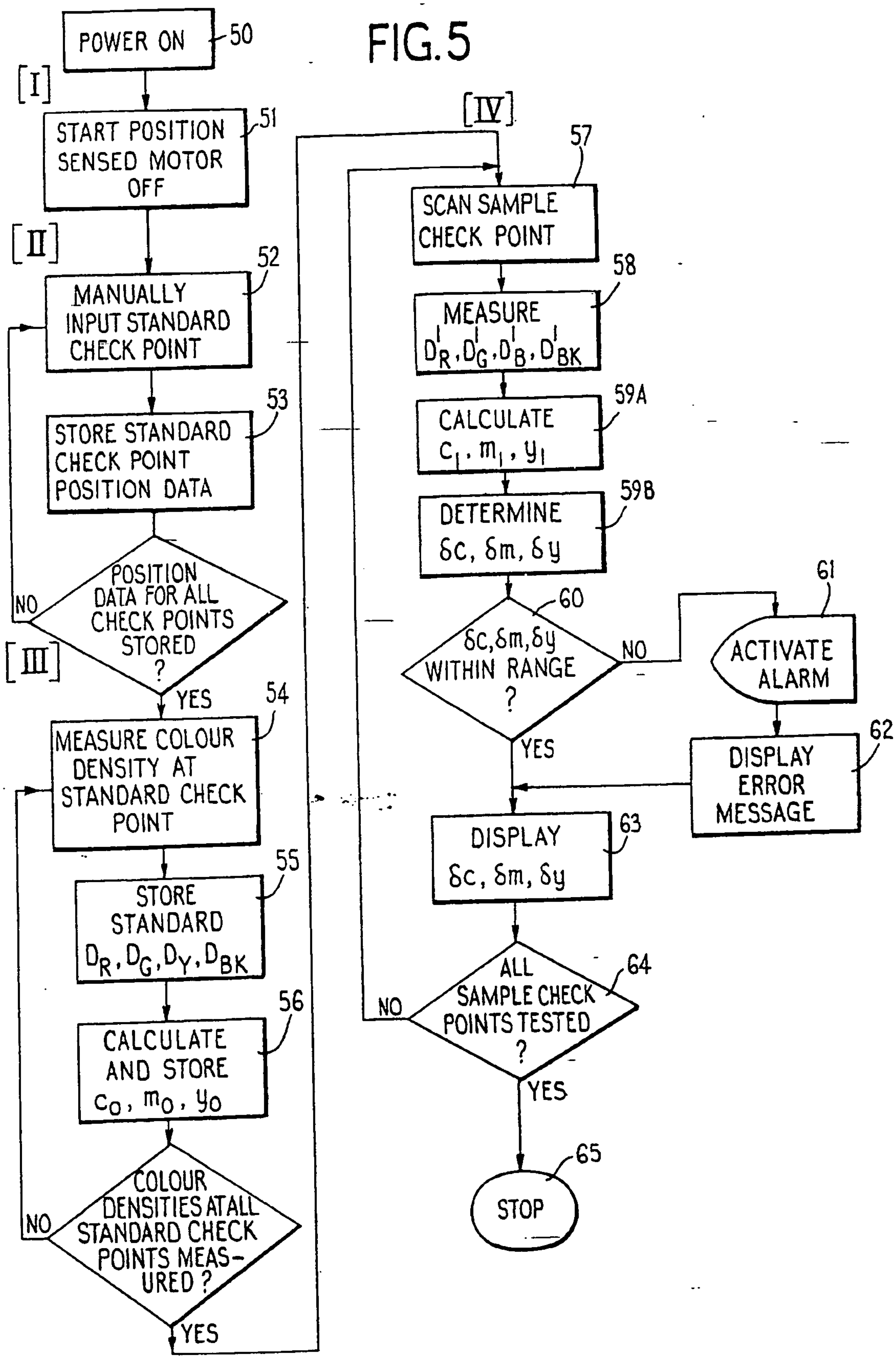


FIG.6

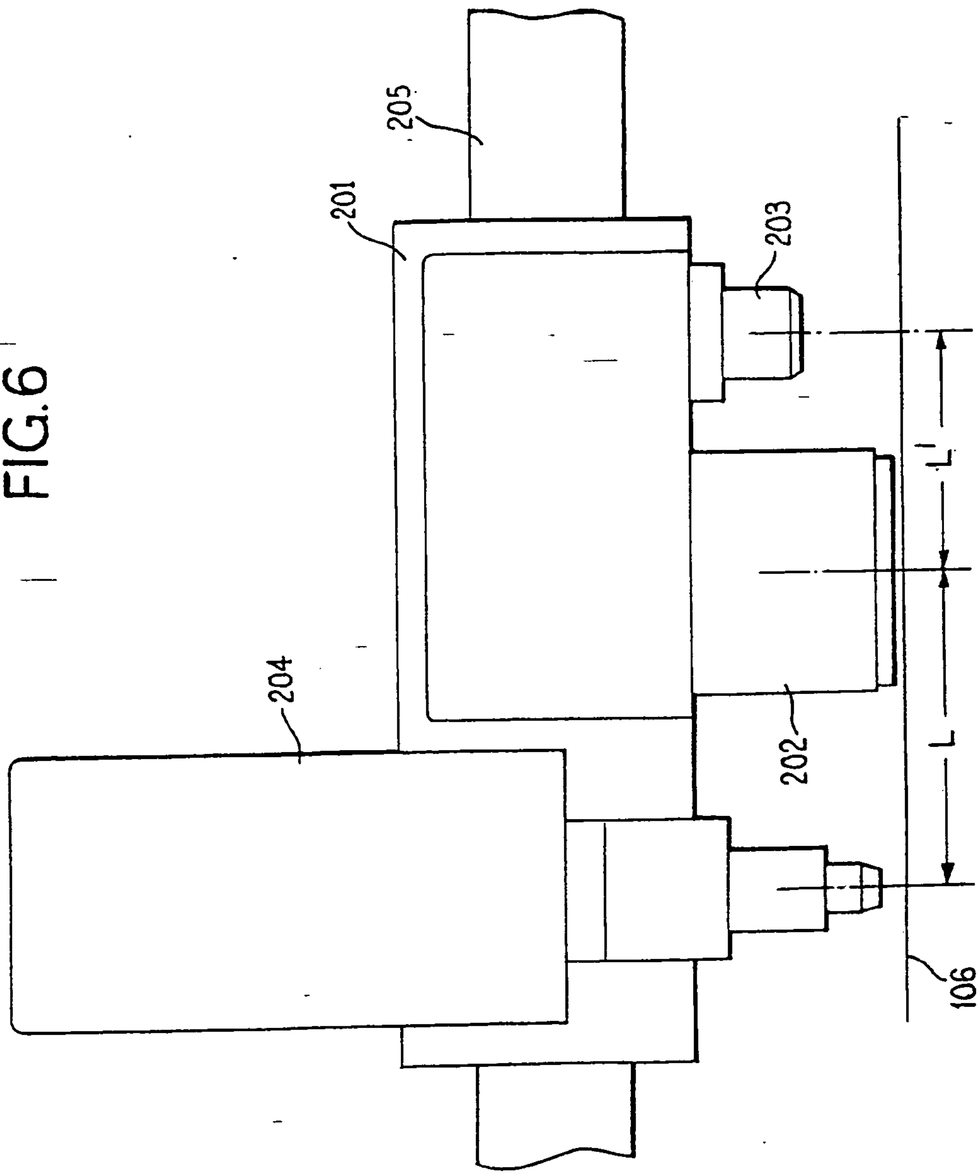
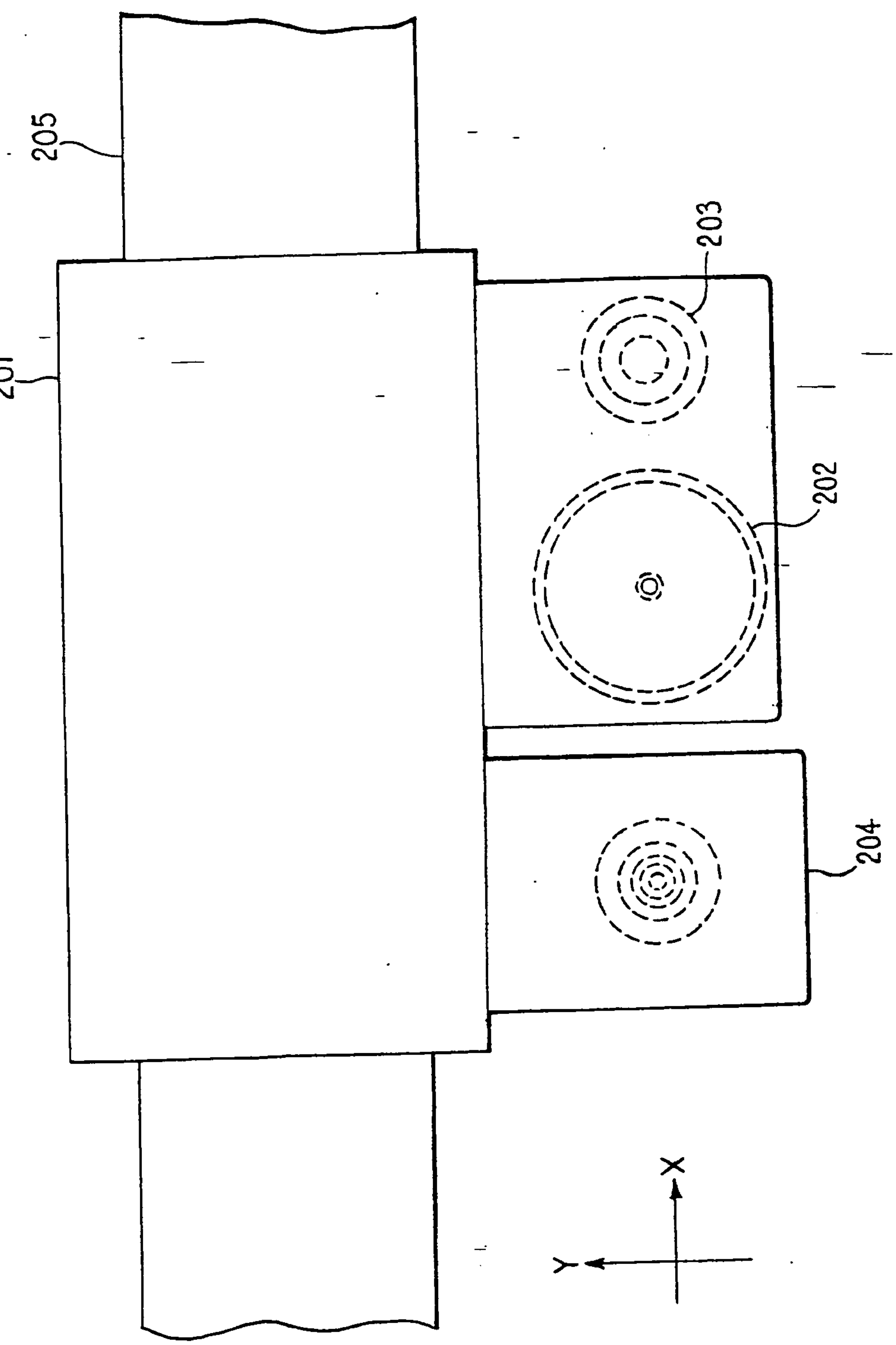


FIG.7



SPECIFICATION

A method and apparatus for measuring ink concentrations in printed matter

This invention relates to a method and apparatus for measuring ink concentrations in printed matter, in particular in colour printed matter, whereby measured concentrations are processed and indicated on suitable means so as to control efficiently ink quantities in a printing press. The invention also relates to an improvement in a measuring head utilized in the apparatus for measurement of ink concentrations.

It has been found to be more difficult to apply a numerical control system to a printing department than to other departments such as processing and correction or retouching departments of a printing works. Therefore, print operators are obliged to give full play to their experience and sharp sixth senses in controlling the printing step, especially in maintaining good quality of the printed matter.

In a printing process, a great number of duplicates should be exactly and uniformly printed and finished in accordance with a single prototype which comprises a standard printed matter normally called an "OK-sheet" and any significant variations in the quality of the duplicates should be avoided. For this purpose, the operators have to control manually the quantities of ink and dampening water used in the process in accordance with their experience and senses.

A number of methods have recently been proposed for substituting the experience required in a printing process with some quantitative means or measure. For example, Japanese Patent laid-open Specification No. 55—55232 discloses apparatus adapted to scan colour patches of primary colour inks deposited on margins surrounding the central surface to be printed. The colour concentrations of the patches are thus measured and compared with standard concentrations. The differences between the measured and standard concentrations are displayed on a video display, for example, television receiver and the ink concentrations in the printed matter are controlled on the basis of the thus displayed differences.

The above described apparatus has, however, some disadvantages. The colour patches must be printed on blank margins or spaces on the printing paper in a direction perpendicular to the printing direction to enable the necessary measurement of the concentrations of the primary colour inks. This necessitates annoying work in processing because precise patterns for the patches must be formed on the cyan (C), magenta (M), yellow (Y) and black (B) printing plates in order to avoid any overlapping of the patches when printing is carried out using each plates in turn. Moreover, the printing paper has to be of larger width, e.g. about 7 mm, than that required for the image to be printed so as to provide the blank margins on which the colour patches are printed and in many cases, it is difficult to reserve such surplus areas on the printing paper. Moreover, the colour patches will inevitably increase ink consumption thereby resulting in higher production costs.

Japanese Utility Model laid-open Specification No. 55—148942 discloses apparatus for detecting ink concentrations in printed matter in which an ink adjusting screw may be remotely controlled. The screw is disposed at an ink fountain of a printing press, and the apparatus thus stabilizes the ink concentrations without use of the above-mentioned colour patches.

This apparatus, like the apparatus described Japanese Patent laid-open in Specification No. 55—55232, also has drawbacks. Thus, it is well known that ink concentrations in some portions of each printed matter or sheet are apt to change in the course of a continuous printing operation whether the printing be an offset or other type of printing system. The change in ink feeding rate cannot be directly detected except in the case of monochromatic printing. In other words, it is almost impossible exactly to detect each of such changes in each feeding rate of a plurality of inks, for example cyan (C), magenta (M) and yellow (Y) inks, when the inks are superimposed in the printed matter with different dot gradations including 100% dot area ratios, that is where the printed matter is completely covered with ink. It is difficult to solve this problem by simple means such as using red (R), green (G) and blue (B) filters to attempt to obtain reasonable differences in filtered densities between a sample or test printed sheet and a standard printed sheet, with respect to the ink feeding rates for the C, M and Y inks. This difficulty arises from the indirect relationship between the densities and the feeding rates and makes it impossible to control successfully the feeding rates in order to restore the densities to the required standard. The experience of a skilled operator will however still be required as well as a noticeably long time to restore the colour densities exactly.

It has also been proposed to utilize a proof press in order to provide proof sheets, the colour densities of which may be used as standards in controlling the principle printing process of a printing press, referred to sometimes as a "principal press". However, ink density differences between the two presses are often caused by differences in the dampening water balances of the presses or by differences in printing pressures. Therefore, such a method will not be effective in stabilizing the printing quality even if the colour density deviations from the proof sheet were indicated for measurement made through R, G and B filters or were regarded as measures for adjusting the feed rates of C, M and Y inks.

Another Japanese Patent laid-open Specification No. 55—55233 discloses a reflective ink densitometer of a type capable of scanning with a movable detector head. In this scanning

densitometer, the movable head is not made to contact check points on the printed matter. Consequently, the head should be large enough to eliminate to a sufficient extent undesirable disturbances caused by light entering the gap between the head and the printed matter. Such a large scanning head is undesirable because it is difficult to determine when its optic axis is in exact alignment with a predetermined check point which results in a loss in accuracy and an insufficient reliability in the quality control of the printed matter.

It should also be noted that in some cases where only ink density measurements are made accurate detection of the printing quality is impossible because of, for example, double printing, slurs or the like. Such incorrectly printed portions have heretofore been observed for analysis thereof by use of a magnifying glass capable of, for example, approximately ×10 magnification to enlarge dots forming the double or slur printed image portions. The portions printed by an incorrect superposition of cyan, magenta and yellow inks are, however, considerably difficult to analyze even for a well skilled person because an optimum magnification can be found only on the basis of vast experience.

It is an object of the present invention to provide a method and an apparatus for measuring ink concentration in printed matter so that ink concentrations may be controlled with a higher effectiveness than achieved with previously proposed apparatus and methods.

According to one aspect of the present invention, there is provided a method of measuring ink concentrations in printed matter, the method comprising: measuring the colour density of check points on a standard printed sheet through a coloured filter or through a plurality of separate differently coloured filters; determining from the colour density measurements the concentration of the or each ink printed on the standard printed sheet at each check point; measuring the colour density of points on a test printed sheet corresponding to the check points on the standard sheet through the same coloured filter or filters; determining, from the colour density measurements for the test sheet, the concentration of the or each ink printed on the test sheet at each point corresponding to a sample sheet check point; and determining for each check point and for the or each colour of ink deviation coefficients representing the difference in ink concentration between the sample and test sheets.

According to a second aspect of the present invention, there is provided apparatus for measuring ink concentrations in printed matter, the apparatus comprising: scanning means for measuring the colour density of check points on a standard printed sheet through a coloured filter or through a plurality of separate differently coloured filters and for measuring the colour density of points on a test printed sheet corresponding to the check points on the standard sheet through the same coloured filter or filters; means for determining from the colour density measurements the concentration of the or each ink printed on the standard sheet at each check point and the concentration of the or each ink printed on the test sheet at each point corresponding to a standard sheet check point; and means for determining, for each check point and for the or each colour of ink, deviation coefficients representing the difference in ink concentration between the sample and test sheets.

Preferably, three separate filters are used, a red filter, a blue filter and a green filter to measure the concentration of cyan, yellow and magenta inks and conveniently the colour densities measured are reflection densities.

Generally, the ink concentrations are calculated in accordance with the following equations:

$$D_1=r_{11}X_1+r_{12}X_2+r_{13}X_3$$

$$D_2=r_{21}X_1+r_{22}X_2+r_{23}X_3$$

$$D_3=r_{31}X_1+r_{32}X_2+r_{33}X_3$$

Where X_1, X_2 and X_3 are the ink concentrations of a first colour ink, a second colour ink and a third colour ink respectively at a check point, or point corresponding to a check point, D_1, D_2 and D_3 are the colour densities at that point measured through a first filter of a fourth colour complementary to the first colour, a second filter of a fifth colour complementary to the second colour and a third filter of a sixth colour complementary to the third colour, respectively, r_{11}, r_{12} and r_{13} are coefficients for the first colour, second colour and third colour components of the first colour ink, r_{21}, r_{22} and r_{23} are coefficients for the first colour, second colour and third colour components of the second colour ink and r_{31}, r_{32} and r_{33} are coefficients for the first colour, second colour and third colour components of the third colour ink.

In a preferred embodiment, reflection densities D_R, D_G, and D_B which are measured on a standard printed sheet by means of a red, a green and a blue filter respectively are thus expressed by the equations:

$$D_R=r_{11}C_0+r_{12}M_0+r_{13}Y_0$$

$$D_G=r_{21}C_0+r_{22}M_0+r_{23}Y_0 \quad (1)$$

$$D_B=r_{31}C_0+r_{32}M_0+r_{33}Y_0$$

Where C_0, M_0 and Y_0 respectively represent printed amounts of C, M and Y inks at any check point.

Similarly, reflection densities measured of a test or sample printed sheet will be expressed by the following equations:

$$\begin{aligned} D_R' &= r_{11}C_1 + r_{12}M_1 + r_{13}Y_1 \\ D_G' &= r_{21}C_1 + r_{22}M_1 + r_{23}Y_1 \qquad (2) \\ D_B' &= r_{31}C_1 + r_{32}M_1 + r_{33}Y_1 \end{aligned}$$

The simultaneous equations are then solved to obtain the values C_0, M_0, Y_0, C_1, M_1 and Y_1 and the differences $C=C_1-C_0$, $M=M_1-M_0$, and $Y=Y_1-Y_0$ are computed and used for the purpose of adjusting feed rates of the C ink, M ink and Y ink. It will be appreciated that any disturbing influence caused by the impurities contained in C, M and Y inks can be eliminated through the above series of procedures.

In a preferred embodiment of apparatus in accordance with the invention, the scanning means comprises density detecting means and magnifying means spaced from the density detecting means. The magnifying means enables easier observation of the check points so that these can be correctly aligned with the optic axis of the density detecting means.

For a better understanding of the present invention and to show how the same may be put into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1A is a graph showing the relationship between colour density and dot area ratio for differing feed rate for any one of the primary inks;

Figure 1B is a graph showing the relationship between colour density and increasing printing pressure;

Figure 2 shows an output produced on a cathode ray tube or by a line printer;

Figure 3 is a perspective view of apparatus in accordance with the invention comprising a colour check stand;

Figure 4 is a block diagram of the apparatus of Figure 3;

Figure 5 is a flow chart illustrating the sequence of steps involved in a method in accordance with the invention;

Figure 6 is a front elevational view of an exemplified sensor head in a movable reflection type colour densitometer; and

Figure 7 is a plan view of the sensor head of Figure 6.

Referring now to the drawings, a first example of a method in accordance with the invention for measuring ink concentrations will now be described with reference to Figures 1A and 1B.

Instead of the colour patches which have previously been marked on multi-colour printed matter some important portions of a picture are selected as check points. At the check points, three colours or inks are usually superimposed on one another and the colour densities thereof are measured so that any variation in printing ink concentration may be analyzed by means of the measurement data.

The three inks are usually cyan (C) ink, magenta (M) ink and a yellow (Y) ink and the theory or principle behind the above-mentioned analysis will be described below with respect to these three inks. As is well known in the art, the actual C, M and Y inks differ in colour from the ideal pure colours. Thus, for example, the C ink comprises a pure cyan component together with impurities which in an ideal ink would be contained only in the M ink or the Y ink. Such impurities also exist in the M and Y inks. Table 1 indicates the amounts of impurities present in each of the three inks by means of the impurities present in each of the three inks by means of the colour density for each measured through, in turn, a red (R), a green (G) and a blue (B) filter, each of the C, M and Y inks being separately printed onto a suitable sheet with a dot area ratio of 100% that is the printing being such that each sheet is completely covered with ink.

Table 1
Colour densities of C, M & Y inks through R, G & B filters

	C ink	*M ink*	*Y ink*
density through R filter	1.79	0.25	0.08
density through G filter	0.55	1.85	0.17
density through B filter	0.22	1.04	1.05

Table 2 indicates the amounts of impurities in each of the three inks. The values given in Table 2 are obtained from those given in Table 1 by scaling the values given in Table 1 so that for each ink the

density through the complementary colour filter is set to be 1.00 (the "predominant density"). Thus, for example, the density through the R filter in the case of the C ink will be scaled to be 1.00 because red is the complementary colour of cyan, this predominant density for the C ink being hereinafter referred to as the "C component".

Table 2
Impurity component ratios for C, M & Y inks

	C ink	*M ink*	*Y ink*
C component ratio	1.000	0.135	0.076
M component ratio	0.307	1.000	0.162
Y component ratio	0.123	0.562	1.000

The densities through R, G and B filters, D_R, D_G and D_B, are approximately represented, for standard printed matter, for any point where the above-mentioned inks are superimposed with either equal or different ratios by the following equations:

$$\begin{aligned} D_R^o &= r_{11}C_0 + r_{12}M_0 + r_{13}Y_0 \\ D_G^o &= r_{21}C_0 + r_{22}M_0 + r_{23}Y_0 \\ D_B^o &= r_{31}C_0 + r_{32}M_0 + r_{33}Y_0 \end{aligned} \qquad (1)$$

where the variables C_0, M_0 and Y_0 represent the amounts or concentrations of each ink printed one upon the other onto check points, and the coefficients or factors r_{11}, r_{12}, . . ., r_{33} are component ratios for the density of each colour through differently coloured filters, in this case R, G and B filters, scaled so that the component ratio for the predominate density is equal to 1.00.

In the example shown in Table 2, the coefficients for the C ink are $r_{11}=1.000$, $r_{21}=0.307$ and $r_{31}=0.123$ while the coefficients for the M ink are $r_{12}=0.135$, $r_{22}=1.000$ and $r_{32}=0.562$ and for the Y ink $r_{13}=0.076$, $r_{23}=0.162$ and $r_{33}=1.000$.

Supposing that colour densities are measured on a regularly printed sample and are found to be D_R', D_G' and D_B' for R, G and B filters respectively, then the densities D_R', D_G' and D_B' will similarly be represented by the following equations:

$$\begin{aligned} D_R' &= r_{11}C_1 + r_{12}M_1 + r_{13}Y_1 \\ D_G' &= r_{21}C_1 + r_{22}M_1 + r_{23}Y_1 \\ D_B' &= r_{31}C_1 + r_{32}M_1 + r_{33}Y_1 \end{aligned} \qquad (2)$$

where the variables C_1, M_1 and Y_1 represent the amounts or concentrations of each ink printed one upon the other on areas of the sample corresponding to the check points.

The colour densities D_R', D_G' and D_B' may each be subtracted from the respective standard colour density D_R, D_G or D_B measured from the check points on the standard printed matter. The differences resulting from such calculations, i.e. $\Delta D_R=D_R'-D_R$, $\Delta D_G=D_G'-D_G$ and $\Delta D_B=D_B'-D_B$, are however not of any practical significance because all of these values are affected in an irregular manner by the amount of the impurity components in the inks. If such difference values alone were used to control ink feed rates, the latter would be changed excessively.

Accordingly, direct differences each computed from the printed concentrations of C, M and Y inks measured in both the standard and sample printed matter are employed. Any error caused by the ink impurity components is eliminated by using the direct differences $\Delta C=C_1-C_0$, $\Delta M=M_1-M_0$ and $\Delta Y=Y_1-Y_0$ so that the ink feed rates can be precisely controlled.

The ink concentrations C_0, M_0 and Y_0 are obtained by solving the simultaneous equations (1) and the ink concentrations C_1, M_1 and Y_1 are similarly calculated from the equations (2). Consequently, each of the ink concentration differences ΔC, ΔM and ΔY can be computed in the following manner, namely:

$$\Delta C=\frac{\begin{vmatrix}\Delta D_R & r_{12} & r_{13}\\ \Delta D_G & r_{22} & r_{23}\\ \Delta D_B & r_{32} & r_{33}\end{vmatrix}}{R}$$

$$\Delta M=\frac{\begin{vmatrix}r_{11} & \Delta D_R & r_{13}\\ r_{21} & \Delta D_G & r_{23}\\ r_{31} & \Delta D_B & r_{33}\end{vmatrix}}{R} \qquad (3)$$

$$\Delta Y=\frac{\begin{vmatrix}r_{11} & r_{12} & \Delta D_R\\ r_{21} & r_{22} & \Delta D_G\\ r_{31} & r_{32} & \Delta D_B\end{vmatrix}}{R}$$

where

$$R=\begin{vmatrix}R_{11} & r_{12} & r_{13}\\ r_{21} & r_{22} & r_{23}\\ r_{31} & r_{32} & r_{33}\end{vmatrix}$$

Deviation ratios also may be obtained, if desired, from the following equations:—

$$\delta C=\frac{\Delta C}{C_0}\times 100$$

$$\delta M=\frac{\Delta M}{M_0}\times 100 \qquad (4)$$

$$\delta Y=\frac{\Delta Y}{Y_0}\times 100$$

The above equations (1) and (2) are not absolutely correct because there exists an irregularity in the addition of algebraic terms (i.e. $r_{11}C_0$, $r_{12}M_0$ etc.) besides irregularities in proportional relations between the variables C_0, M_0, Y_0 etc and the algebraic functions D_R, D_G, D_Y etc. However, it should be noted that small variations in the ink concentrations are not of relevance so that such irregularities do not affect the validity of the equations (3) for the present purposes.

It is necessary when applying the equations (3) to determine beforehand the coefficient r_{11}, r_{12}, . . . , r_{33}. These factors may be obtained by measuring colour densities by means of R, G and B filters for each of the available inks, each ink being individually printed onto paper with a dot area ratio of 100%. Where some of these coefficients are sufficiently small they may be neglected or treated as being zero.

Strictly speaking, the factors coefficients r_{11}, r_{12}, ..., r_{23} vary slightly for each ink in dependence on, for example, the dot area ratio which may range from 0% to 100% in the sample. However, the values of the coefficients for a dot area ratio of about 50% are close to the average values so that, if desired, these values may be used in place of those for dot area ratios of 100%. If a still greater precision is required, different coefficients may be used for each check point dependent on its dot area ratio. For this purpose, a series of coefficients for each ink and each filter are previously determined at regular intervals through the whole range of dot area ratios. Such precision will not however be needed in practice since the method will be applied solely to the control of small deviations in ink concentration.

The above method can also be easily applied to the occasional case where a black BK ink is present besides the heretofore mentioned three primary inks, namely cyan, magenta and yellow inks. Where the variations in the BK ink concentration are negligible then the above method can be applied without modification. However, where the variation is likely to be great, it is necessary to employ means to analyse the variations in the concentration of the BK ink at the check points where the ink is printed so that any influence of this ink may be subtracted from the other principal data.

Alternatively, in the absence of one of the C, M and Y inks, a coloured filter for the "predominant density" of the absent ink will be excluded and the sets of three simultaneous equations (1) and (2) will be reduced in each case to two simultaneous equations with resulting modification of the equations (3). Of course, where a particular check point in the printed image comprises only one ink, only one filter, namely a filter of the colour complementary to the ink present at the check point will be used to detect the predominant density thereof.

In the event that one or more particular inks having colours different from the normally used C, M and Y inks is used in place of one or more of the normally used inks, the concentrations of these particular inks will be checked by means of the equations (3) or simplified forms thereof at printed points where two or three of these particular inks are superposed. As for the other printed points where only one of the particular inks is printed, it will be sufficient to utilize one filter selected from R, G, B and W (transparent to visible light) filters so as to check the colour density variation at the monochromatic points.

Several examples of further processing and/or use of the data obtained by the above method will be described below.

Figure 1A is a graph illustrating the variation in detected ink concentrations with dot area ratio, for different ink feed rates, the solid line representing a standard ink feed rate while the dotted lines illustrate the effect of an increase or decrease in the ink feed rates in a printing press. It will be seen from Figure 1A that the coefficients δC representing the percentage deviation of the ink density from the standard density are nearly equal to each other.

Variation coefficients representing the percentage deviation of the ink density from the standard are calculated in the following manner from the equations (4), namely

$$\delta C_H=100\times(C_{H1}-C_{H0})/C_{H0}(\%)$$

$$\delta C_m=100\times(C_{m1}-C_{m0})/C_{m0}(\%) \qquad (5)$$

$$\delta C_S=100\times(C_{S1}-C_{S0})/C_{S0}(\%)$$

These equations exemplify the case for the cyan (C) ink and will result in values of δC_H, δC_m and δC_S which are nearly equal to each other notwithstanding the positions of check points, that is, highlight (H), middle (m) or shadow (s) portions in the printed matter as can be seen from Figure 1A. A warning signal will appear on an indicator or alarm to instruct an operator to adjust the ink feed rate when the deviation C coefficients exceed an upper or lower predetermined limit. The same will of course apply for the magenta (M) and the yellow (Y) inks. The alarm signal will normally be arranged to be produced when the deviation coefficients representing the deviation of the ink density from a chosen standard density for highlight, average and shadow portions are nearly equal to each other and are outside a predetermined allowable range for the test printed sheet under inspection.

Figure 1B illustrates graphically the variations in ink density with dot area ratio for different printing pressures. In Figure 1B the solid line represents a standard pressure while the dotted lines represent an increase or decrease in pressure in a running printing machine. A warning signal will occur on an indicator and/or an alarm when for example the deviation coefficient C_H for the C ink concentration in the highlight portion (H) becomes much larger than that for the middle portion (m) and exceeds a predetermined limit, to instruct an operator to adjust the printing pressure.

In multi-colour printing it is sometimes found that a later printed ink, for example, the second ink, does not transfer well onto an earlier printed ink, for example, the first ink, which has not dried sufficiently. This phenomenon is referred to below as "poor trapping". In general, the deviation coefficient of ink concentrations on the shadow portion (s) where the dot area ratio is nearly 100% will increase more markedly than that in the middle portion (m). When the deviation coefficient for the shadow portion (s) exceeds a predetermined limit, an indicator and/or alarm will be activated to warn the operator that 'poor trapping' has occurred.

When an acute change in the deviation coefficient for the concentration of an ink cannot be attributed to any of the above-mentioned causes, the possible cause of such change would normally be a bad balance between the amounts of ink and the dampening water. Again a warning signal instructing an adjustment of the balance will be given on an indicator and/or an alarm where the deviation coefficients for highlight, average and shadow portions of a test sheet are different from one another, and the deviation coefficients for the highlight portion and the shadow portion are so much smaller than that for the average portion that the highlight and shadow portion deviation coefficients are outside predetermined allowable ranges for the test printed sheet under inspection.

In each of the above cases, the deviation coefficients for the C, M and Y inks are indicated on a cathode ray tube or on a printer. However it would be more beneficial in each of the above cases to use a colour filter for measuring brightness of each check point and thereby to indicate a difference in the colour density of a sample print from a standard. Such data will be indicated on the cathode ray tube (CRT) or on the printer together with the deviation coefficients for the C, M and Y ink concentrations so that the latter can be checked easily with the human eye. Figure 2 is an example of the output graphs produced on the CRT or printer, the graph M% indicating that the magenta ink concentration has exceeded the higher limit at a check point designated as "1".

Apparatus in accordance with the invention for use in the above method will now be described by reference to Figures 2 to 5.

As shown schematically in Figure 3, the apparatus comprises a base 100 having provided thereon a sloping or oblique table 102 adapted to receive a printed sheet 106. A rail 103 is secured to

each of the sloping edges of the table. A frame 104 movably connected to the rails 103 carries a scanning head 105 which is movable across the frame. Thus, the head 105 can be placed over any desired position on the table 102 by movement in the directions indicated by arrows 107 in Figure 3.

A control panel 108 and CRT units 109, are disposed on a front portion of the base 100 so as to be easily operable, the panel and units being suitable for processing and displaying measurement data.

On a rear portion of the base 100, there is provided an upstanding or vertical plate 111 to which is secured a standard printed sheet 110. A roof 112 of the apparatus having standard light sources 113 fixed thereto is disposed above the upstanding plate 111 so that light is directed downwardly from the light sources 113 through a honeycomb structure or grid 114 disposed beneath the roof 112. Curtains 115 depend from the side edges of the roof in such a manner that they may be extended and withdrawn in the directions indicated in Figure 3 by the arrows 116 so as to shield the table 102 from any unwanted light.

The operation of the apparatus will now be described by reference to Figures 4 and 5.

In a first stage I of the process, a power source switch (not shown) on the control panel 108 is activated as indicated by step 50 in Figure 5 in order to drive pulse motors 31 and 32 respectively by means of motor drive circuits 33 and 34 which are in turn activated via an interface 28 by a central processing unit (CPU) 22 having stored therein a program to energize the circuits 33 and 34. The motors 31 and 32 under the control of the CPU 22 drive the scanning head until 105 and the frame 104 respectively until the scanning head and the frame 104 are returned to their starting points. Thus, the scanning 105 is moved across the frame 104 that is in an X-direction by means, for example, of a drive screw operably connected to one of the motors 31 and 32. The frame 104 itself is moved along the rails 103 by the other motor, the movement of the frame being defined to be in a Y-direction. Position sensors 35 and 36 are also connected to the interface 28 and are adapted to detect a starting point mark to stop both the motors and keep the head stationary of the starting point (X_0, Y_0) (step 51 in Figure 5).

The standard printed sheet 110 is then placed on the oblique table 102 and an end of the sheet is brought into correct alignment with a proper indicating means (not shown) so that the sheet 110 may be positioned at a predetermined correct position of the table 102 and be fixed thereon by suction means (Stage II).

Subsequently, switches provided on the control panel 108 are activated to control manually movement of the scanning head 105 by means of the motors 31 and 32. The scanning head 105 is thus moved toward the first check point and temporarily held stationary thereat (step 52 in Figure 5). Button switches on the panel 108 are then pushed or activated in order to store data representing the position of the check point in the CPU (step 53 in Figure 5), this operation being repeated until the position data for all the check points has been stored in the CPU. The apparatus is now preset and Stage II of the process complete. Of course either the operator will determine when the required number of check points have been scanned or alternatively the CPU 22 may be instructed to accept a given number of check points.

After the presetting has been completed, measurement of the colour densities of the standard printed sheet is initiated by pushing the correct switches (not shown) on the panel 108 Stage (III). The head 105 is thus automatically driven in accordance with a prestored program (step 54 in Figure 5) and the colour densities at all of the check points are measured one after another, each measurement being performed with the R, G, B and W filters which give the colour densities D_R, D_G, D_B and D_{BK} which are fed into the CPU 22 via an interface 23 (step 55 in Figure 5).

The CPU 22 then determines from the colour density data the ink concentrations Co, Mo and Yo (step 56 in Figure 5) at each check point, the coefficients rij (where i=1, 2 or 3 and j=1, 2 or 3) having already been supplied to a temporary or "semi-fixed" data storage device 27 and fed to the CPU 22 via an interface 26 and a bus 1. The coefficients rij depend of course on the types of ink used.

It will be apparent that the colour density data can, alternatively, be supplied to the CPU simultaneously with the check point position data.

Once the preliminary measurement has been completed and the ink concentrations Co, Mo and Yo for the standard printed sheet have been stored in the CPU 22, then, inspection or testing of a sample printed sheet chosen, for example at random, from the printed sheets being continuously produced and discharged by a printing press can be begun (Stage IV). The sample sheet is first aligned correctly on table 102 and then fixed in place by the suction means, and a starting button switch (not shown) on the panel 108 is activated to drive the head 105 so that is passes one after another over the positions on the sample sheet corresponding to the check points (step 57 in Figures 5).

Thus, colour densities D'_R, D'_G, D'_B and D'_{BK} are measured by the sensor head (step 58 in Figure 5), and thereafter the CPU 22 computes the ink concentrations C_1, M_1 and Y_1 (step 59A in Figure 5), which are in turn compared with the formerly obtained concentrations Co, Mo and Yo for the standard point so as to give the deviation coefficients (defined in the equations (4) mentioned above (step 59B in Figure 5)). The CPU 22 then determines whether the deviation coefficients fall within predetermined allowable ranges or not (step 60 in Figure 5). Where the coefficients fall within the allowable ranges, they are graphically displayed on the CRT unit 109 connected to the CPU 22 via interfaces 24 and 25 respectively (step 63 in Figure 5). A sample of such a display is shown in Figure 2.

However, if the deviation coefficients lie outside the allowable ranges, a warning signal will be given on an alarm means 30 such as a warning lamp, chime or the like connected to the CPU 22 by interface 29 (step 61 in Figure 5) so that the operator promptly becomes aware that there is an abnormal condition in the printing process. One of the following suitable instructions or comments, namely:

(a) "ink feed rate should be adjusted";
(b) "printing pressure should be adjusted";
(c) "tendency for poor trapping"; and
(d) "ink-water balance incorrect"

is displayed on the CRT 109 or other indicating means (step 62 in Figure 5).

The CPU then determines whether all of the check points have been inspected (step 64 in Figure 5). If all check points have been tested, the routine program will stop (step 65 in Figure 5). However, if all check points have not been tested, the CPU 22 will activate the motors 31 and 32 to scan the next check point and steps 57 to 63 will be repeated. After completion of a testing or inspection procedure, the operator adjusts the printing press according to the instructions.

When the data has been displayed, the fourth stage, that is steps 57 to 63, will be repeated for each further test or sample sheet.

The above procedure can of course also be applied to the variables per se, instead of the coefficients thereof.

The apparatus described above can thus correctly detect ink concentration variation for each sample check point, and is not affected by the irregular relationship between ink concentration and colour density. The apparatus also allows a warning signal as well as an instruction or comment based on analysis of the abnormalities detected to be given so that even an inexperienced operator can easily and promptly adjust the press, thereby reducing loss of materials. If the apparatus is provided in a conventional colour check stand, visual inspection will make the control more effective. Moreover, a control circuit may be connected to the apparatus in a manner so that the circuit automatically controls operation of the printing press in accordance with the data received from the apparatus.

Figures 6 and 7 illustrate a colour density measuring head assembly, that is a scanning head assembly which is particularly suitable for use with the apparatus described above.

The scanning head assembly comprises a head holder 201 movable in the X-direction along a frame 205 which is movable in the Y-direction. The head holder 201 incorporates a density detector 202, a lighting means such as a spotlight 203 to facilitate confirmation of check point positions, and a video or TV camera 204 provided with a microscope lens (having a magnification of approximately 150), the detector, spotlight and camera being fixed to the holder such that the midpoints of the camera 204 and the detector 202 are separated by a distance L′ and the detector 202 and spotlight 203 by a distance L.

A magnifying projector may be used in place of the TV camera 204 and the camera or projector will be referred to hereinafter as "magnifying means".

In operation, the spotlight 203 is switched on to illuminate a check point under examination which is to be discriminated from the background of the printed sheet 106. When a density measurement is conducted, the head holder 201 will be shifted by the distance L′ between the spotlight 203 and the density detector 202 so that the check point comes into alignment with the optic axis of the detector.

In order to observe the shape of a dot within the check point, the scanning head is similarly moved by the distance L between the detector 202 and the magnifying means 204 to bring the optic axis of the microscope lens attached to the magnifying means into alignment with the check point. An image signal from the magnifying means is sent to a monitor, preferably a colour monitor, to produce thereon a magnified image of the dot. The magnified image is desirably of approximately 150 the size of the dot so that several people can observe it at the same time.

Where several check points are selected on the printed sheet 106, the spotlight 203 should be brought to the selected points one after another and correctly focused thereupon, so that the X—Y coordinates of each check point can be fed to a memory device and stored. The distance L′ is then subtracted from (or added to) the stored values in order that correct position for alignment of the detector 202 may be determined. The detector 202 thus can be correctly aligned with the position of a check point during motion of the scanning head. The colour densities of a plurality of check points may thus be automatically measured with a high precision as well as a high efficiency.

It is of course possible to conduct a density measurement immediately after the spotlight 203 has been focussed on a measurement check point, the distance L′ being subtracted or added to the position before the density measurement begins.

The above-described scanning head assembly is capable of being used not only in reflection densitometry as described above, but also in transmission densitometry. A viewer of low magnification may also be used instead of the spotlight, which may alternatively be provided adjacent the microscope lens of the TV camera.

The above-described assembly ensures correct alignment of check points with the optical axis of the detector in a movable density measuring head. The magnifying means, for example a TV camera having a microscope lens, which replaces the conventional magnifying glass, allows an extremely enlarged picture of a fine dot to be produced so that some unskilled operators can all observe it at the same time, for example with the skilled operator in charge, and analyze any discrepancy or slur therein with ease and precision for the purpose of a more effective inspection of print quality.

Claims

1. A method of measuring ink concentrations in printed matter, the method comprising: measuring the colour density of check points on a standard printed sheet through a coloured filter or through a plurality of separate differently coloured filters; determining from the colour density measurements the concentration of the or each ink printed on the standard printed sheet at each check point; measuring the colour density of points on a test printed sheet corresponding to the check points on the standard sheet through the same coloured filter or filters; determining, from the colour density measurements for the test sheet, the concentration of the or each ink printed on the test sheet at each point corresponding to a sample sheet check point; and determining for each check point and for the or each colour of ink deviation coefficients representing the difference in ink concentration between the sample and test sheets.

2. A method according to Claim 1 and further comprising displaying the difference values on display means.

3. A method according to Claim 1 or 2, wherein three separate filters are used, a red filter, a blue filter and a green-filter to measure the concentration of cyan, yellow and magenta inks.

4. A method according to Claim 1, 2 or 3, wherein the colour densities measured are reflection densities.

5. A method according to Claim 1, 2, 3 or 4, wherein the ink concentrations are calculated in accordance with the following equations:

$$D_1=r_{11}X_1+r_{12}X_2+r_{13}X_3$$
$$D_2=r_{21}X_1+r_{22}X_2+r_{23}X_3$$
$$D_3=r_{31}X_1+r_{32}X_2+r_{33}X_3$$

Where X_1, X_2 and X_3 are the ink concentrations of a first colour ink, a second colour ink and a third colour ink respectively at a check point, or point corresponding to a check point, D_1, D_2 and D_3 are the colour densities at that point measured through a first filter of a fourth colour complementary to the first colour, a second filter of a fifth colour complementary to the second colour and a third filter of a sixth colour complementary to the third colour, respectively, r_{11}, r_{12} and r_{13} are coefficients for the first colour, second colour and third colour components of the first colour ink, r_{21}, r_{22} and r_{23} are coefficients for the first colour, second colour and third colour components of the second colour ink and r_{31}, r_{32} and r_{33} are coefficients for the first colour, second colour and third colour components of the third coloured ink.

6. A method according to Claim 5, wherein the first, second and third colours are cyan, magenta and yellow respectively and the fourth, fifth and sixth colours are red, green and blue respectively.

7. Apparatus for measuring ink concentrations in printed matter, the apparatus comprising: scanning means for measuring the colour density of check points on a standard printed sheet through a coloured filter or through a plurality of separate differently coloured filters and for measuring the colour density of points on a test printed sheet corresponding to the check points on the standard sheet through the same coloured filter or filters; means for determining from the colour density measurements the concentration of the or each ink printed on the standard sheet at each check point and the concentration of the or each ink printed on the test sheet at each point corresponding to a standard sheet check point; and means for determining, for each check point and for the or each colour of ink, deviation coefficients representing the difference in ink concentration between the sample and test sheets.

8. Apparatus according to Claim 7, wherein display means are provided for displaying the concentration difference values.

9. Apparatus according to Claim 7 or 8, wherein three separate filters are provided, a red filter, a blue filter and a green filter to measure the concentration of cyan, yellow and magenta inks.

10. Apparatus according to Claim 7, 8 or 9, wherein the apparatus is arranged to measure reflection densities.

11. Apparatus according to Claim 7, 8, 9 and 10, wherein the ink concentration determining means are arranged to determine the ink concentrations in accordance with the following equations:

$$D_1=r_{11}X_1+r_{12}X_2+r_{13}X_3$$
$$D_2=r_{21}X_1+r_{22}X_3+r_{23}X_3$$
$$D_3=r_{31}X_1+r_{32}X_2+r_{33}X_3$$

Where X_1, X_2 and X_3 are the ink concentrations of a first colour ink, a second colour ink and a third colour ink respectively at a check point, or point corresponding to a check point, D_1, D_2 and D_3 are the colour densities at that point measured through a first filter of a fourth colour complementary to the first colour, a second filter of a fifth colour complementary to the second colour and a third filter of a sixth colour complementary to the third colour, respectively, r_{11}, r_{12} and r_{13} are coefficients for the first colour, second colour and third colour components of the first colour ink, r_{21}, r_{22} and r_{23} are coefficients for the first colour, second colour and third colour components of the second colour ink and r_{31}, r_{32} and r_{33} are coefficients for the first colour, second colour and third colour components of the third colour ink.

12. Apparatus according to any one of Claims 7 to 11, wherein the ink concentration difference determining means is arranged to produce an indication that the ink feed rates should be adjusted when the deviation coefficients representing the deviation of the ink density from a chosen standard density for highlight, average and shadow portions are nearly equal to each other and are outside a predetermined allowable range for the test printed sheet under inspection.

13. Apparatus according to any one of Claims 7 to 12, wherein the ink concentration difference determining means is adapted to produce an indication that a printing pressure should be adjusted when the deviation coefficient for a highlight portion of the test sheet is greater than that for an average portion and is outside a predetermined allowable range for the test printed sheet under inspection.

14. Apparatus according to any one of Claims 7 to 13, wherein the ink concentration deviation determining means is adapted to indicate a bad trapping when the deviation coefficient for a shadow portion of a test sheet is greater than that for an average portion and is outside a predetermined allowable range for the test sheet under inspection.

15. Apparatus according to any one of Claims 7 to 14, wherein the ink concentration deviation determining means is adapted to produce an indication that a balance between the ink and dampening water is incorrect when the deviation coefficients for highlight, average and shadow portions of a test sheet are different from one another, and the deviation coefficients for the highlight portion and the shadow portion are so much smaller than that for the average portion that the highlight and shadow portion deviation coefficients are outside predetermined allowable ranges for the test printed sheet under inspection.

16. Apparatus according to any one of Claims 7 to 15, and further comprising a colour check stand.

17. Apparatus according to any one of Claims 7 to 16, wherein the scanning means comprises density detecting means and a magnifying means spaced from the density detecting means.

18. Apparatus according to Claim 17, wherein the magnifying means comprises a video camera having a microscope lens attached thereto and video display means operable with the camera.

19. Apparatus according to Claim 17 or 18, wherein the scanning means further comprises a light source means spaced from the density detecting and magnifying means for aligning the scanning means with a check point or point corresponding to a check point.

20. Apparatus according to Claim 19, wherein the light source means is arranged to emit a spotlight beam is setting the scanning means in alignment with a check point or point corresponding to a check point.

21. A method of measuring ink concentrations in printed matter substantially as hereinbefore described with reference to the accompanying drawings.

22. Apparatus for measuring ink concentrations in printed matter substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

23. Any novel feature or combination or features described herein.

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